IDEC Chip Design Contest

Temperature Sensor Analog Front-End with Low-Noise Chopper-Stabilized Delta-Sigma Converter

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ABSTRACT

This paper proposes a temperature sensor analog front-end with low-noise chopper-stabilized delta-sigma converter. The proposed sensor analog front-end equipped with a fully integrated temperature sensor can drive voltage signals by direct conversion without a front-end amplifier. A chopper stabilization technique is implemented here to achieve a low-noise characteristic by reducing unexpected low-frequency noises such as offsets and flicker noise. The prototype chip of the proposed sensor analog front-end is fabricated by a standard 0.18 µm complementary metal-oxide-semiconductor (CMOS) process with an active area of 0.375 mm^2. The total power consumption is 0.843 mW with a 1.8 V power supply.

INTRODUCTION

- The bandgap reference is one of the most popular reference voltage generators that successfully achieve the stability over process, voltage, and temperature variation.
- The conventional three-transistor bandgap cell works well for very low voltage two-terminal or synthetic diode requirements, but is less flexible in three-terminal applications and in circuits where the desired output is not an integral multiple of the bandgap voltage.
- The two-transistor cell presented here is simpler, more flexible in three-terminal applications.
- To reduce the area and power consumption, the direct delta-sigma conversion can be a good solution.
- The proposed temperature sensor analog front-end can drive voltage signals without a front-end amplifier by direct conversion in the delta-sigma converter scheme, and it also employs a chopper stabilization technique to achieve a low-noise characteristic.

CIRCUIT IMPLEMENTATION

- Fully integrated temperature sensor analog front-end
  - The proposed temperature sensor analog front-end comprises an offset calibration block, and programmable gain amplifier.

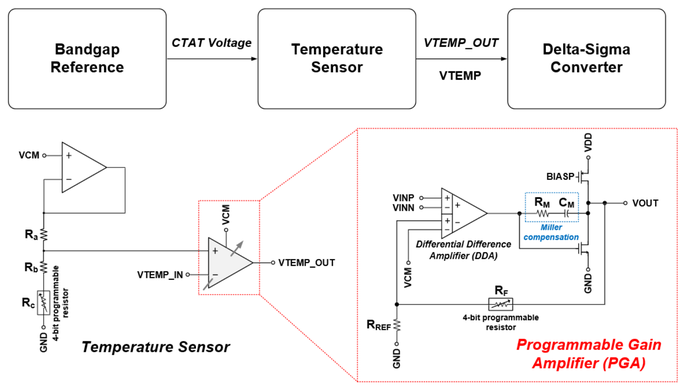

Fig. 1. Schematic of the fully integrated temperature sensor

- Circuit Operation of the proposed temperature sensor analog front-end
  - The temperature sensor consists of an offset calibration block and the programmable gain amplifier. The offset voltage of the temperature sensor is obtained as:

$$V_{OFFSET} = \left(\frac{R_b + R_c}{R_a + R_b + R_c}\right) \cdot VCM \tag{1}$$

  - The programmable gain amplifier is implemented using a differential difference amplifier. The gain of the programmable gain amplifier is controlled by the 4-bit programmable resistor R_F. the output voltage of the temperature sensor is obtained as:

$$VTEMP = \left(1 + \frac{R_F}{R_{REF}}\right) \cdot (V_{OFFSET} - VTEMP\_IN) + VCM \tag{2}$$

  - The output bandgap reference voltage (VBGR) is generated by ratios of the resistors R_1, R_2, R_3 and R_4, following as:

$$VBGR = \left(\frac{R_4}{R_1}\right) \cdot V_T \cdot \ln(n) + \left(\frac{R_4}{R_3}\right) \cdot VEB_{Q2} \tag{3}$$

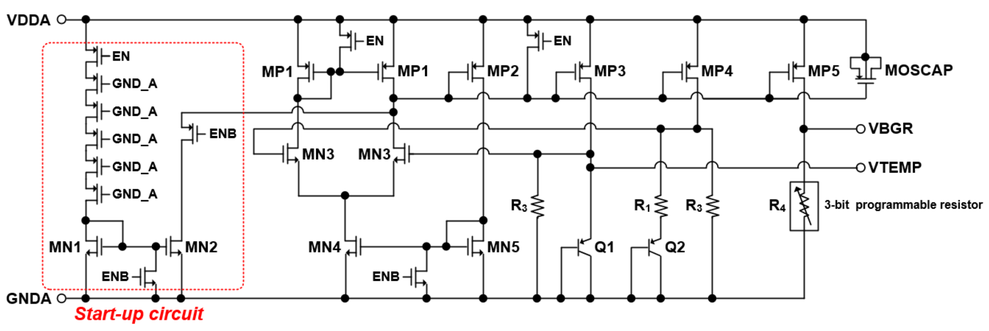

Fig. 2. Schematic of bandgap reference of the fully integrated temperature sensor

EXPERIMENTAL RESULT

- Dig photograph and measurement environment

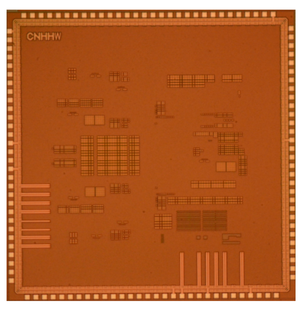

Fig. 3. Die photograph of the fabricated chip

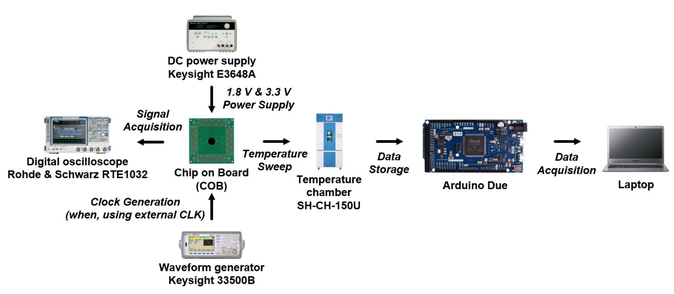

Fig. 4. Measurement environment

- The measured output data of the temperature sensor with the proposed sensor analog front-end integrated circuit
  - The measured temperature range is −10 °C to 120 °C with 10 °C step.
  - The output was compensated with two-point nonlinearity fitting.

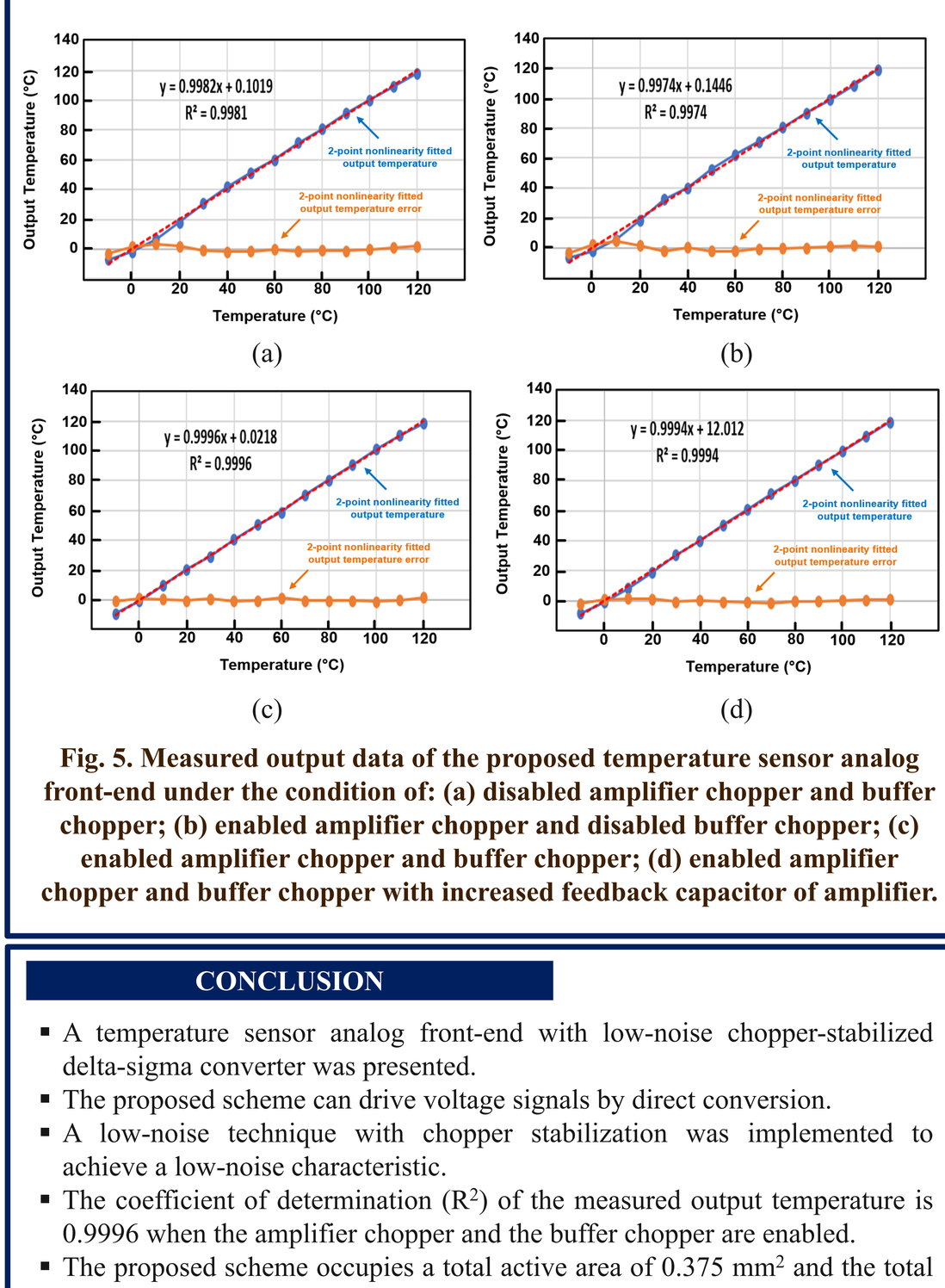

Fig. 5. Measured output data of the proposed temperature sensor analog front-end under the condition of: (a) disabled amplifier chopper and buffer chopper; (b) enabled amplifier chopper and disabled buffer chopper; (c) enabled amplifier chopper and buffer chopper; (d) enabled amplifier chopper and buffer chopper with increased feedback capacitor of amplifier.

CONCLUSION

- A temperature sensor analog front-end with low-noise chopper-stabilized delta-sigma converter was presented.
- The proposed scheme can drive voltage signals by direct conversion.
- A low-noise technique with chopper stabilization was implemented to achieve a low-noise characteristic.
- The coefficient of determination (R^2) of the measured output temperature is 0.9996 when the amplifier chopper and the buffer chopper are enabled.
- The proposed scheme occupies a total active area of 0.375 mm^2 and the total power consumption is 0.843 mW with a 1.8 V power supply.

ACKNOWLEDGEMENT

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